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"Designing to Support Command and Control in Urban Firefighting"

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14. ABSTRACT
Recent fire disasters (e.g. 2000 Fireworks Factory, Enschede, NL; 2001 World Trade Center Attacks, NYC; 2007 Airline crashed into fuel warehouse, Sao Paolo, BR) have highlighted the need for support to incident commanders in emergency response situations. Contrary to technologists who introduce designs which are often clumsy and do not support critical tasks, human factors engineers take a problem-centered approach. This research and design project begins with a functional analysis of firefighting based on observations, interviews, doctrinal literature reviews, accident analysis, and simulations. The functional analysis then provides the design requirements for systems to support command and control for urban firefighters. These systems include personal tracking/alerting/communication devices, an interface for incident commanders, vehicular interfaces for fire companies, and an overarching architecture to support cross-echelon and interagency coordination. Recommendations are also made for improving Emergency Operations Centers. Findings from this project will provide unique insight for military command and control and inform decision makers about a design approach that applies to the development of future complex human-machine systems.

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Designing to Support Command and Control in Urban Firefighting

Abstract

Recent fire disasters (e.g. 2000 Fireworks Factory, Enschede, NL; 2001 World Trade Center Attacks, NYC; 2007 Airline crashed into fuel warehouse, Sao Paolo, BR) have highlighted the need for support to incident commanders in emergency response situations. Contrary to technologists who introduce designs which are often clumsy and do not support critical tasks, human factors engineers take a problem-centered approach. This research and design project begins with a functional analysis of firefighting based on observations, interviews, doctrinal literature reviews, accident analysis, and simulations. The functional analysis then provides the design requirements for systems to support command and control for urban firefighters. These systems include personal tracking/alerting/communication devices, an interface for incident commanders, vehicular interfaces for fire companies, and an overarching architecture to support cross-echelon and interagency coordination. Recommendations are also made for improving Emergency Operations Centers. Findings from this project will provide unique insight for military command and control and inform decision makers about a design approach that applies to the development of future complex human-machine systems.

Keywords: Command and control, firefighting, cognitive systems engineering, cognitive task analysis

Introduction

"Eyewitnesses spoke of limbs flying through the air and dead bodies lying in the smoking rubble" (BBC, 2000).

On May 13, 2000, 20 people were killed and 300 injured when a fireworks warehouse located in a residential neighborhood in Enschede, Netherlands exploded. Ironically, eight months earlier, a similar fireworks explosion had killed 50 and injured 300 in Celeya, Mexico (BBC, 1999). On 17 July 2007, at least 50 rescue vehicles responded after a TAM Airlines Airbus 320 skidded into a building in the heart of Sao Paulo, Brazil, killing at least 200 (CNN.com, 2007). On September 11, 2001, over 10000 rescue personnel responded to the attacks on the World Trade Center (CNN.com, 2001). Although emergency responders are well-prepared for the vast majority of daily incidents, these and other recent fire disasters have highlighted the need for support to incident commanders in extraordinary situations. This paper illustrates a human-centered approach to design and provides some initial recommendations for tools to support command and control in urban firefighting.

Firefighting has two goals: save lives and protect property. Intense environmental and time pressures, and the emergency response organizations themselves can confound these goals in large scale incidents. Decisions to achieve these goals are often made under ambiguous, frequently changing conditions and require information from a variety of sources. Facilitating shared awareness of the situation across all echelons allows for local and strategic adaptations to help achieve the organizations goals.

As a supervisory control system, firefighting organizations are resilient when supervisors have the ability to impart their expertise to support local actors (i.e. the individual responder), while retaining their global perspective. "High-Reliability Organizations" within domains such as nuclear power generation, military operations, space exploration and emergency response, typically rely on rapid pattern-based human decision-making (Rochlin, et al., 1987; Weick & Sutcliffe, 2001). These organizations must maintain greater flexibility in rules and procedures in order to cope with ever-changing situations in responding to emergencies. Military organizations achieve this by making the commander's intent explicit (Shattuck & Woods, 2000). For example, a firefighting organization may include many separate but coordinated units operating in tandem to accomplish the same goal. Coordination breakdowns between any one of these units can result in catastrophic consequences for the others.

An analysis of the Mann Gulch fire disaster of 1949, in which 13 firefighters died, has served as the basis for our understanding of sensemaking in organizations (Weick, 1995). Sensemaking describes our continual effort to create order in the world and make sense of the past and present. It is an ongoing process that requires individuals to properly interpret available cues and make rational sense of their environment. Sensemaking is inextricably tied to the context of the situation and involves matching patterns based on one's experience base. Errors in sensemaking occur when individuals are unable or unwilling to assimilate unanticipated changes because the current situation does not match a familiar experience. The deaths of the 13 firefighters were largely attributed to the inability of the firefighters to change their original perception of

the fire and make sense of cues that were inconsistent with that perception. An inability to correctly make sense of the world can invariably lead to erroneous decision making and, particularly in high-cost environments, may result in similar organizational disasters.

Gary Klein (1985) examined decision making among fireground commanders during critical incidents (i.e. big fires). Commanders were interviewed because they are responsible for making the high-stake decisions, such as how to attack fires and utilize crews, in urban and suburban fires. Traditional models of decision making suggest that we generate and evaluate multiple alternatives until we reach an optimal decision. In time pressured environments, this is too time consuming and decision makers are primarily concerned with finding workable rather than optimal solutions. In these situations, decision makers rely on their experience in order to generate an initial reasonable option and do not consider another course of action unless there is evidence that their chosen course of action is not workable. Furthermore, decision makers monitor how well their course of action will work by imagining how it will be carried out, rather than by formal analysis and comparison. Given this understanding of how firefighters make decisions, it is imperative that any support tools be designed to help the entire organization leverage existing knowledge bases to address novel situations.

Organization and Automation in Emergency Response

Emergency response organizations are diverse and hierarchical and often form multiple command centers as an incident develops. For example, the Fire Department of New York has over 14000 members and includes not only individuals responsible for fighting fires, but also medical treatment, hazardous material mitigation and search and rescue. Time-phased resource staging can result in groups vying for control rather than being solely concerned with the emergency at hand. Oomes and Neef (2005) acknowledge the need for information systems to support the proper build-up of an emergency response organization, starting with the smallest possible unit and remaining effective and useful throughout the entire process, aiding the organization shape itself into the most appropriate form at the correct time.

Heath and Luff (1992) found that attempts to modernize the control rooms of the London Underground with computerized displays failed due to removing artifacts in the environment around which effective coordination had naturally evolved. Cues to other actors' workload and to the state of the systems they were monitoring were lost. It is suggested that aiding individual agents in determining the state of another agent is critical to supporting collaborative work; affordances should thus be designed to encourage mutual understanding by individual actors. Allowing actors to manipulate each other's work space is also suggested, thereby creating a shared work space for physically separated actors.

In situations such as emergency response, time pressure may prevent synchronous collaboration of actors who must still maintain common situational awareness, especially pertaining to the actions of other actors. Landgren (2005) proposes a technological solution to collect "traces of action," enabling the actors to visualize the status of collaborative work, as well as providing documentation for later

analysis. A study of a Swedish fire and rescue service's use of information technology revealed that attempts to provide devices to support documentation during an incident failed for multiple reasons:

- The devices focused on textual input instead of speech, which is the primarily means of communication during most emergency response situations.
- Documentation focused on landmark events and decisions; however, during emergency response, there may be no obvious moments of decision, but rather a continual focus on making sense of the situation at hand, from which action naturally results.
- Performing documentation of actions takes time that could be spent performing actions that address the emergency situation.

Instead of focusing on events, Landgren suggests capturing otherwise fleeting information streams, such as radio communications, and making them available both during and after emergency response work. Rather than focus on key landmark events, traces of action, the ongoing modification of plans and action in the face of changing consequences, should be captured.

Clumsy automation typically results from poor design processes (Woods, Hollnagel, 2006). Developers may miss higher demand situations due to insufficient knowledge about the field of practice. They may also misread or rationalize away the evidence of trouble created by their designs. Oftentimes they may not recognize near catastrophes due to the skill of practitioners in working around and adapting to poor support tools. Therefore, researchers have advocated the use of ethnographic methods for functional analyses that capture the dynamic nature of work (e.g. Rasmussen, Pejtersen, Goodman, 1994; Elm, Potter, Gualtieri, Roth, & Easter, 2004) in domains such as firefighting.

Methods

"Developing a meaningful understanding of a field of practice relies on multiple converging techniques" (Potter, Roth, Woods & Elm 2000). We began this project with a review of firefighting doctrine and curriculum taught at a firefighting academy. Hutchins (1995) has noted that written procedures are not used by practitioners as structuring resources and they are not reflective of tasks that are performed. While doctrine, written operating procedures, and historical accounts are not truly indicative of the real work performed, they are a valuable starting point for further discovery. They serve as a basis for orienting and educating new practitioners in the domain, can reflect what is viewed as best practice, and provide an invaluable introduction to domain language and expectations for the researcher.

Building on these activities, we conducted unstructured interviews with practitioners of varying experience, including firefighters, company officers and chiefs. Firefighters are responsible for individual duties such as operating fire apparatus, ventilating fire buildings, conducting searches, and rescuing occupants with experience

ranging from six months to 10 years. Company officers are responsible for supervising four or five other fighters and have five to 15 years of experience. Chiefs have the most experience (10 to 25 years) and are responsible for supervising two or more fire companies. Most chiefs also have experience serving as incident commanders. Interviews during the preliminary stage of our research were typically informal and conducted during the course of their normal duties. During these interviews we asked each practitioner to describe their duties and responsibilities and asked them to describe work situations in which they were surprised or forced to adapt from their normal operating procedures. Due to the limitations of self-report data (Stone, et al., 2000; Howard, 1994), our team also observed daily operations and training exercises.

Our team of six researchers observed daily operations, incident responses and training exercises over the course of eight days. While shadowing fire chiefs in four different firehouses, our team observed a fire safety inspection, four fire emergencies, a steam pipe leak, a hazardous material release and multiple false alarms. Additionally, we observed a variety of training exercises. Two full-scale exercises, one at a high-rise commercial building and one at a shopping mall, included multiple fire battalions responding to large-scale, simulated crises. Two table-top exercises were venues for interagency planning and coordination. As well, two company-level training exercises focused on individual firefighter and small team actions at an emergency. Table 1 summarizes our participants and observations.

Table 1 – Observations and Interviews

Observations	***Unstructured Interviews***	***Guided Interviews***
5 Urban Firehouses (8 days w/ 6 observers)	7 x Fire Chiefs	1 x Fire Chief
<u>Exercises</u>	3 x Company officers	1 x Company Officer
2 x Full-scale exercises (High Rise & Shopping Mall)	4 x Firefighters	1 x Firefighter
2 x Table-top exercises (Shopping Mall & Government agency coordination meeting)		
2 x Company training exercises (rope training, hose training)		
<u>Emergency Responses</u>		
2 x Apartment fires		
Trash fire		
Residential basement fire		
Steam Pipe leak		
15 x False alarms		

Findings

This ethnographic data resulted in a Functional Goal Decomposition which indicates the critical functions, decisions and information requirements for firefighting (see also Fern, Trent, & Voshell, 2008). We have found that firefighting has five functions: Manage Routes, Manage Resources, Reduce Threats, Situation Assessment, and Extraction. Managing routes includes planning and executing movement to and from the incident and includes negotiating local paths at the incident. Managing resources includes monitoring, committing, requesting and withdrawing personnel, equipment and supplies. Reducing threats entails extinguishing, containing or dissipating fire, hazardous material or other environmental hazards to life and property. Situation assessment includes gathering intelligence, monitoring, and assessing the state of the threat, and progress or effectiveness of the response. Extraction includes removing occupants or incapacitated firefighters from danger. Table 2 summarizes these functions, the decisions that support each, and lists the information required for the decisions. Future iterations of this work will utilize process traces of critical incidents in order to illustrate interdependencies and the dynamics of decision making in firefighting.

Table 2 – Functional Goal Decomposition of Firefighting

Goals	***Save Lives*** ***Protect Property***	
Function	**Decisions**	**Information Requirements**
Manage Routes	What route to take for approaching the incident? Where to lay hose lines? What are the valid entry/exit paths? Does a path need to be created?	Infrastructure limitations Traffic patterns Routes of other responders Environmental conditions Occupancy status Confirmed life hazard Condition of roof Locations of: Incident Water sources Fire or contamination Extensions of fire or contamination Elevators, stairs, doorways, access points Obstacles for entry
Manage Resources	When and where to commit resources? When to withdraw or replace resources? When to request resources? Who to designate as a safety team? Where to establish command post and staging areas? When to request casualty coordinator? How to position ladders and pumps?	Progress of search Conditions in building Occupancy status Water supply Resource depletion Expertise/Trust in working groups Time units have been exposed Current staffing levels Unique apparatus available Status of uncommitted units Emergency responder casualties Structure type and floor plan Street conditions

		Locations of: Fire or contamination Extensions of fire or contamination Life hazards Resources Power lines Water sources Building entrances Other vehicles
Reduce Threat	Whether to attack or contain the fire? Reduce or contain contaminants? Need to set up/establish decontamination? Whether to ventilate or not? What substance(s) to use on contaminants or fire? Where to attack threat?	Structure type and floor plan Conditions in building Type of contamination Surrounding population Weather effects on contaminants Locations of: Fuel sources Fire or contamination Extensions of fire or contamination Hose lines Scuttles and skylights
Situation Assessment	Is it a false alarm? Cease or continue search for life? Cease of continue search for fire? Where to search?	Source of alarm Reports from occupants Presence of heat or smoke Fire containment Occupancy status Progress of search Exposures Structure type and floor plan Potential for flash over/ back draft Resource depletion Time of day Locations of: Fuel sources Fire or contamination Extensions of fire or contamination Hose lines Scuttles and skylights Stairs Life hazard Small rooms
Extraction	Focus on threat reduction or rescue? Where to establish a safe refuge area? What is the best method for evacuation? When to deploy a rescue team?	Presence of ladder company Water supply Conditions in building Occupancy status Location of: Fire or contaminants Extension of fire or contaminants Stairs, balconies, fire escapes, elevators, exits Rescue teams Incapacitated or Lost emergency responder

Designing for Fire Command

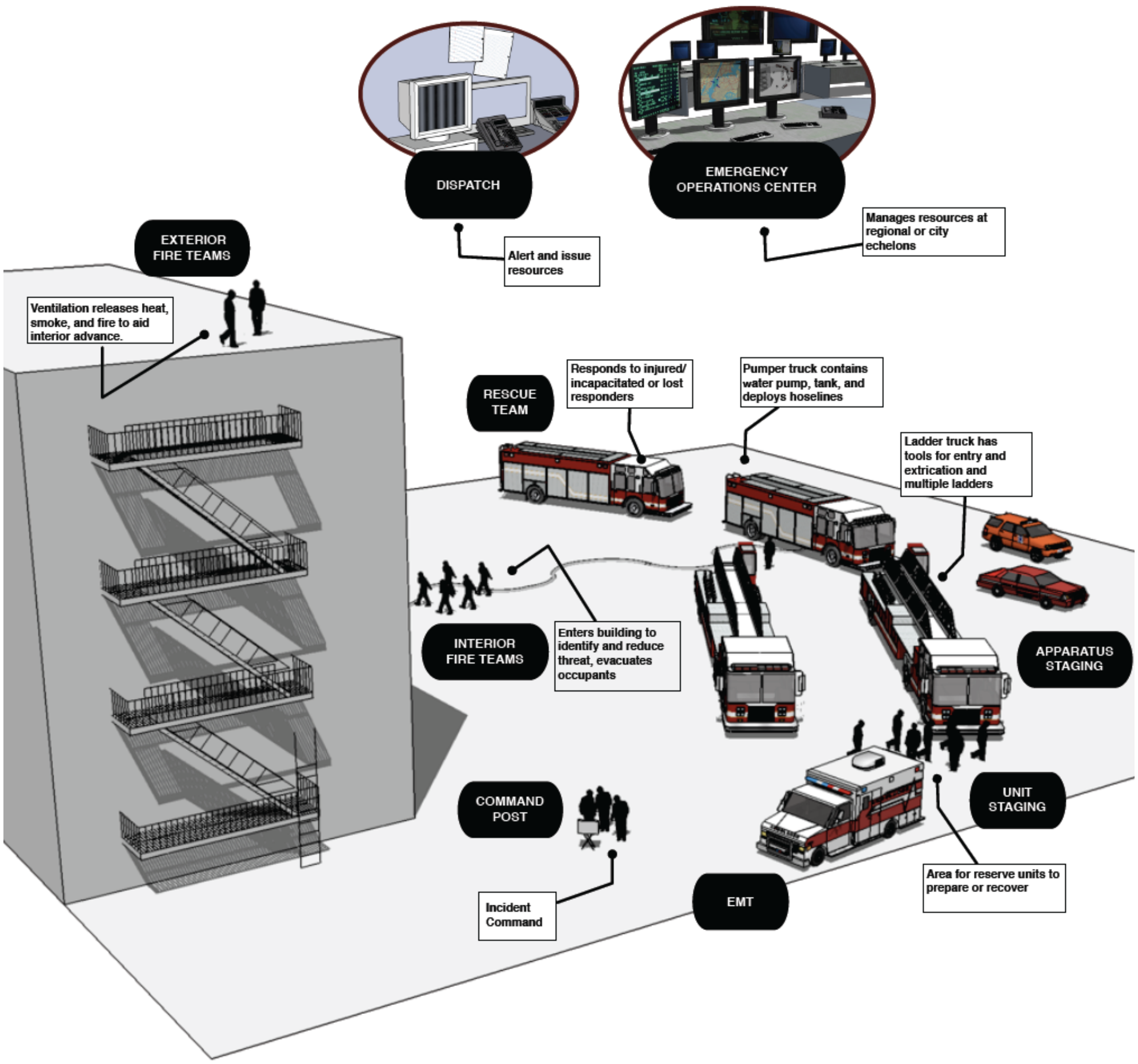


Figure 1 – Critical elements in urban fire command

Support tools are often designed by considering only one node for decision making (e.g. the commander, an analyst at a workstation, the pilot). For federated system such as urban fire command, we need to understand the broader system and its interdependencies first. Figure 1 depicts critical elements in urban fire command as it is conducted today. This section describes initial design requirements for some of these critical nodes. Highlighted in each subsequent figure are the predominant functions performed at those nodes.

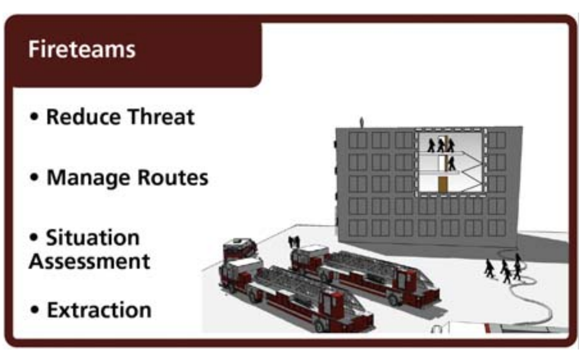
Incident Command and Communications

We observed only single channel Motorola hand-held radios for all tactical communication in and around incidents. This severely limits the ability of firefighters to communicate over long distances and in heavily built-up areas. Single channel communications also force multiple working groups onto one network with multiple network communications only possible with multiple radios. This clutters these critical coordination loops, discourages some communications in favor of network traffic discipline and creates added bulk to firefighters.

Multi-channel communication systems which use ground and aerial vehicles as retransmission platforms would allow command teams (i.e. fire chiefs and their aides) to monitor and interact on multiple echelon networks. A network priority toggle would allow for individuals to switch between networks while still using a single handheld device. Retransmission of handhelds through other platforms with extended transmit and receive capabilities would reduce the interference of physical structures.

Many incident commanders rely on notepads and dry erase boards for tracking and monitoring resources. As incidents escalate, resource management becomes more difficult and incident commanders require greater support. Resilient support tools must support routine as well as extraordinary operations. An automated support tool should afford commanders critical information about the incident en route to and throughout the incident. The primary functions of this support tool should be resource management and gathering/sharing intelligence about the situation. As such, it should provide near real time information regarding location and disposition of resources (e.g. manpower, vehicles, and supplies), structures, and threats (i.e. fire or contamination). It should also be capable of providing the medical treatment chiefs with information regarding hospital capacity, expertise and resources. This support tool should allow both the chief and his aide the ability to update and view information necessary for decision making. It should facilitate the sharing of voice, data and video feeds with Emergency Operations Centers and should be automatically updated with situational information from the Fire Teams.

Fire Teams

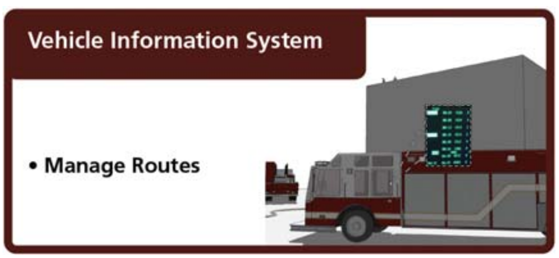


Firefighters are the most important, resilient and adaptive resource that fire departments have. However, most fire departments are limited to verbal reports via FM radio from individual firefighters for tracking their locations. The only automated alerting device is designed to identify firefighters who become incapacitated. The version of this alarm that we observed is subject to many false alarms, and is often viewed as a distracter for firefighters. Protective gear protects

firefighters from extreme heat and debris, but reduces environmental cues of hazardous conditions. Finally, firefighters experience limited range of motion and are rapidly exhausted due to the weight and bulk of their existing equipment.

Firefighters would likely benefit from a device that integrates voice/data communications, alerting and geo-positioning. This device should provide situational alerts (i.e. heat, smoke, injured or lost firefighters) as well as communication with their units and commanders. Given the amount of stimuli firefighters already process in visual and auditory channels, it is likely that tactile alerts may prove best at directing attention to environmental dangers. This device should not rely solely on GPS for tracking as reception is often hampered by obstructions. It is likely that GPS in conjunction with an inertial motion detector would provide requisite fidelity. Location, personal identification and environmental data for each firefighter should be transmitted digitally each time a firefighter keys his microphone or at regular intervals. This device should be for personal wear and should be no more bulky/heavy than a handheld radio. The interface for this device should be usable in extreme conditions (i.e. with firefighting gloves, in zero illumination, intense heat, water-soaked).

Vehicle Information System



We observed a system for collecting and disseminating critical information for incidents that was limited to 160 characters. This constraint results from the limited bandwidth of a copper wire network which was installed in the early 1900s for relaying alarms from manual pull boxes. It is likely that other major metropolitan fire departments experience limitations on the amount and type of information they can receive about an incident. Modern communications architectures would support a graphical command interface within fire vehicles. This interface should direct the attention of firefighters to important factors related to the incident (i.e. location of fire, building construction, location of water sources, downwind hazard areas etc.). This interface should indicate age and source of data in order to inform commanders about trustworthiness.

Most fire departments rely on the experience of drivers for route identification. However, turnover resulting from promotions, retirements, or casualties can create deficits in experience. Other common changes in large cities can interfere with good route selection: firefighters responding to incidents outside their normal area of operations, construction, traffic and maintenance on water sources. A GPS navigation system, which relays location data to dispatchers, and incident commanders, should offer route planning advice to drivers. An independent terminal for other members of the company could provide them with critical information about the incident.

Emergency Operations Center

Most Emergency Operations Centers (EOC) only support decisions of city or regional authorities. However, they have access to information that would also be helpful for incident commanders. Critical information for urban firefighters is in multiple forms and is maintained by many agencies (i.e. transit authorities, building commissions, contractors, and firehouses). For large cities, compiling and maintaining an accurate database on these structures will take an extensive amount of time and manpower. Although maintenance of this database might need to be federated across many agencies, EOCs should be prepared to push important information to incident commanders throughout an incident.

The complex nature of command and control at an Emergency Operations Center (EOC) demands personnel that are appropriately skilled. These organizations are often manned by emergency responders who are on medical profiles or other temporary duty status. This limits their ability to perform tasks for which they are trained (i.e. fighting fires) and creates motivation, innovation and skill deficit challenges. EOCs should be staffed with personnel trained specifically for supporting strategic as well as tactical decision makers.

Conclusion

This paper has summarized the progress of an ongoing and extensive project to understand and design for command and control in complex environments. Because all of our data has been collected within one major metropolitan fire department, these findings must be verified elsewhere to ensure sufficient external validity. In the next phase of this project, our team is conducting a meta-analysis of 50 critical incident investigations. These narratives will provide further information about the nature of breakdowns in this domain and help us accurately capture the dynamics of the interdependent work in emergency response. General patterns extracted from this analysis will be the basis for representative large-scale emergency response scenarios to be used in training exercises, research studies and support tool design. In other words, the analysis, scenarios and design seeds used throughout this project are being used as shared representations to elicit further feedback for future improvements and refinements.

At a minimum, this project yields important insight into effective design methods that should be used elsewhere - particularly in military command and control and interagency coordination activities. For instance, it is rare to find operational-level command and control centers which are designed through a formal functional analysis. Quite the opposite, most begin with the goal of creating a theater of computers oriented on a wall-sized monitor displaying the news. Tools and workspaces designed in this way (i.e. technology is the goal) are often underutilized and poorly supportive of the team collaboration necessary for daily and crisis situations. Additionally, our approach to system design yields important information about the skills and information needed to

support such diverse workgroups. Although incremental improvements can be realized through other design methods, this project is demonstrating the value of an iterative design process which is problem-centered and invests heavily in domain orientation.

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References

BBC News. *Dutch fireworks disaster.* 14 May 2000. http://news.bbc.co.uk/2/hi/europe/747566.stm Accessed on 26 December 2007.

BBC News. Mexico explosions kill dozens. 27 September 1999. http://news.bbc.co.uk/2/hi/americas/458438.stm Accessed on 26 December 2007.

CNN.com. Fiery plane crash at Sao Paulo airport kills at least 200. 18 July 2007. http://www.cnn.com/2007/WORLD/americas/07/17/brazil.plane.crash/index.html Accessed on 26 December 2007.

CNN.com. Terror attacks hit U.S. 11 September 2001. http://archives.cnn.com/2001/US/09/11/worldtrade.crash/index.html Accessed on 26 December 2007.

Elm, W.C., Potter S.S., Gualtieri, J.W., Roth, E.M., & Easter, J. R. (2004). Applied Cognitive Work Analysis: A programmatic methodology for designing revolutionary cognitive affordances. In Hollnagel (Ed) Handbook for Cognitive Task Design. London: Lawrence Erlbaum Associates, Inc.

Fern, Trent, & Voshell (2008). A functional goal decomposition of urban firefighting. In proceedings of the 5th *International Security Crisis Response and Management (ISCRAM) Conference*, Washington, D. C.

Potter, S. S., Roth, E. M., Woods, D. D. & Elm, W. (2000). Bootstrapping multiple converging cognitive task analysis techniques for system design. In J.M.C. Schraagen, S.F. Chipman, & V.L. Shalin, (Eds.), *Cognitive Task Analysis*. (pp. 317-340). Mahwah, NJ: Lawrence Erlbaum.

Rasmussen, J., Pejtersen, A., Goodman, L. (1994). *Cognitive Systems Engineering*. New York: Wiley.

Landgren, J. (2005) Shared Use of Information Technology in Emergency Response Work: Results from a Field Experiment. In proceedings of the *2nd International ISCRAM Conference*, Brussels. Belgium. 35-41

Heath, C. and Luff, P. (1992) Collaboration and Control: Crisis Management and Multimedia Technology in London Underground Line Control Rooms, Computer Supported Cooperative Work, Vol. 1, No. 1-2, 69-95

Howard, G.S. (1994). Why do people say nasty things about self-reports? *Journal of Organizational Behavior*, *15*, 339-404.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Oomes, A., Neef, R. (2005). Scaling-up support for emergency response organizations. In proceedings of the *2nd International ISCRAM Conference*, Brussels. Belgium.

Rochlin, G. I., LaPorte, T.R., and Roberts, K.H. (1987). The Self Designing High Reliability Organization: Aircraft Carrier Flight Operations at Sea, Naval War College Review, Autumn, 1987, 76-90.

Shattuck, L., Woods, D. (2000). Communication of intent in military command and control systems. In C. McCann & R. Pigeau (Eds), *The human in command: Exploring the modern military experience*. New York: Plenum.

Stone, A., Turkkan, J., Bachrach, C, Jobe, J, Kurtzman, H., & Cain, V. (Eds) (2000). *The Science of Self-report: Implications for research and practice*. Mahwah, NJ: Lawrence Erlbaum.

Weick, K. E. (1995) *Sensemaking in organisations*. Thousand Oaks: SAGE Publications Inc.

Weick, K.E. and Sutcliffe, K.M. (2001). *Managing the unexpected: Assuring high performance in an age of complexity.* New York: Jossey-Bass.

Woods, D., Hollnagel, E. (2006). *Joint Cognitive Systems*. New York: Taylor & Francis.